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TEST AND EVALUATION OF LIQUID POLYMERS FOR USE IN ARMY WEAPON COMPONENTS

Wilbur M. Veroeven

Army Weapons Command
Rock Island, Illinois

October 1972

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TECHNICAL REPORT

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RESEARCH DIRECTORATE
WEAPONS LABORATORY, WECOM
RESEARCH, DEVELOPMENT AND ENGINEERING DIRECTORATE
U. S. ARMY WEAPONS COMMAND

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13 ABSTRACT

High durometer (65 to 85 Shore D) compounds based on liquid polyether urethane polymers were developed by personnel of the Research Directorate, Weapons Laboratory, WECOM. Weapons components fabricated from these compounds were tested in the laboratory. Properties of the cured compounds investigated were pot life; stress-strain; environmental stability; resistance to various fluids and semifluids; shear, torsional, bending and compressive strengths; and impact resistance at +75°F and -67°F. The addition of 0.5 pphr of fine thermal carbon black to the polymers gave good resistance to 500 hours of ultraviolet (UV) exposure in a Weather-Ometer. The addition of 0.75 pphr of Wing Stay T to the black pigmented compounds further improved the UV resistance, but with a reduction in original stress-strain properties. Fluid resistance was excellent for these materials, with the exception of their resistance to gasoline and insect repellent. Rifle butt stocks and artillery handwheels fabricated from these polymers are superior to currently used stocks and handwheels fabricated from filled phenolic plastics. (U) (Veroeven, Wilbur M.)

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CONTENTS

OBJECTIVE

The objective of this project was to compound and test castable polymers for potential use in the fabrication of lightweight, high impact-resistant, low-cost weapon components.

INTRODUCTION

Results of previous evaluations[1] of castable polymers indicated that liquid polyether urethanes have potential for use in certain weapon applications. The major effort of this earlier investigation involved the castable urethanes in the lower (90 and less) Shore A hardness range. Late in this previous program, urethanes in the higher (65 to 85) Shore D hardness range indicated potential use for several weapon applications such as butt stocks, butt pads, and artillery handwheels.

For the higher Shore D hardness urethanes to be useful in the aforementioned applications, a number of factors required investigation. This investigation included (1) a determination as to whether the pot life of the resin hardner mixture was long enough to permit hand casting of end items without deterioration of physical properties, (2) an assessment of the best method of compounding to achieve optimum properties, (3) the determination of the effect of a wide range of environmental outdoor conditions on the materials, and (4) an appraisal of the resistance of the material to various servicing fluids used for lubricating and cleaning weapons, and to nonservicing fluids with which they might be in contact

Determination was also necessary as to whether the fabrication of specific weapon end items was technically possible on a laboratory scale. Therefore, the M16A1 butt stock/butt pad and artillery handwheels were utilized as test vehicles to further evaluate the liquid urethane materials.

[1]Veroeven, W M., "Castable Elastomers and Plastics for Weapon System Components," Research Directorate, Weapons Laboratory at Rock Island, Technical Report RE-TR-71-57, August 1971.

In this report, the compounding and the materials evaluation are covered, plus the fabrication and the laboratory evaluation of weapon end items based on liquid polyether urethane elastomers.

PROCEDURE

1. Laboratory Mixing and Casting of Liquid Polymers

a Mixing (Adiprenes and Vibrathane)

(1) Resin was weighed into a resin kettle (fitted with a thermometer, vacuum line, and agitator) of sufficient size to hold the resin and allow for volume expansion during deaeration.

(2) The resin was heated to 180°F with stirring under a vacuum of 5mm mercury or less until bubble formation stopped.

(3) The vacuum was broken and the molten curative added to the hot resin.

(4) Curative and resin were thoroughly hand mixed, and precautions were taken to minimize air entrapment.

(5) The mixed resin was cast into the appropriate mold (test pad or end item), preheated to 212°F, and cured in an air oven for the times listed in Table I.

b. Mixing (Castethane X139-16-1)

The method used was essentially that recommended by the manufacturer.

(1) Component B at 75°F was weighed into a beaker of sufficient size to allow for volume expansion during deaeration

(2) The required amount of Component A was added at 75°F, and the two components were thoroughly mixed.

(3) The mixture was placed under a vacuum of 5mm of mercury or less until bubble-free

(4) The mixed resin was cast into a mold at 75°F and cured for 24 hours at 75°F.

TABLE I

PHYSICAL PROPERTIES OF LIQUID POLYETHER URETHANE VULCANIZATES

Ingredients	U80-46	U80-58	U80-49	U80-57	U80-62	U80-71	U80-63	U80-69	U80-72
	Parts by Weight								
Adiprene L-315	100		100	100					
Adiprene LD-955		100			100	100	100		
Upjohn CPR X139-16-1								**	
Vibrathane B604									100
MOCA	26	25.8			25.8	25.8			
Curene L			29.3	29.3			29		30.6
P-33 Black/TOF Blend*	1		1	1	1	1	1		1
Wing Stay T				0.75		0.75			
Cure. Time/Temp °F	1 hr/212	6 hrs/212	18 hrs/212	18 hrs/212	6 hrs/212	6 hrs/212	18 hrs/212	24 hrs/75°F	6 hrs/212
Postcure @75°F & 50% R.H.	14 days	14 days	14 days	14 days	14 days	14 days	14 days	14 days	14 days
Physical Properties									
Original tensile, psi	6210	8520	7270	5420	8290	6820	7970	7910	7100
100% M, psi			5110	4980	4460	4540	4710		5760
200% M, psi					7410				
Elongation, %	190	270	160	105	220	180	190	10	140
Hardness, Shore D	70	67	77	75	72	70	73	78	77
After 500 hrs. in Weather-Ometer:									
Tensile, psi			4400	4870	5910	6060	5550	7870	5290
100% M, psi					4530	4790	4810		
Elongation, %			85	100	125	155	130	10	100
Hardness, Shore D			76	77	74	74	78	82	79
Shear strength, psi	4320		4640	4720	4490	4440	4930	5150	5540

*See procedure section for details

**65.4 parts by weight of Component A/34.6 parts by weight of Component B

c. Casting

Standard test pads (0.075 X 6 X 6 inch) were cast with a commercially developed mold, which has a large reservoir at the top and into which the liquid polymer was poured and then allowed to flow down to fill the test slab area. In this design, air is forced down ahead of the liquid polymer and is then vented upward and out through vent channels on either side of the mold. This mold design is being considered as a standard by Subcommittee D11.24 of ASTM Committee D11 for casting liquid urethanes.

2. Testing

Stress-strain properties were determined on specimens cut by Die C of ASTM Method D412-68[2] These specimens were tested with an Instron TTCM1 tester at a crosshead speed of 1 inch per minute

Hardness was determined according to ASTM Method D2240-68.

Changes in properties of elastomeric vulcanizates resulting from immersion in liquids were obtained by ASTM Method D471-72

Shear strength was measured on cylindrical specimens 0.25 inch in diameter and 1 inch in length. The steel fixture used to hold the shear specimen consisted of an outer sleeve with outside dimensions of 1 X 1 X 3 inches and an inner hollow core 0.50 inch square running the length of the sleeve A 0 50-inch square plunger 3 inches in length was fitted snugly into this sleeve. A 0.25 inch hole was drilled through both the sleeve and the plunger; the center was located 1.5 inches from either end of the sleeve and 0 31 inch from one end of the plunger Shear strength was determined as follows: the holes in the plunger and in the sleeve were aligned, the specimen was inserted and the force required to shear this specimen determined. This force was applied to the plunger at a rate of 0 05 inch per minute

[2]ASTM Standards, Part 28, Rubber, Carbon Black, Gaskets American Society for Testing and Materials, Philadelphia, Pennsylvania (1972)

Ultraviolet radiation exposures were run in an Atlas Type XW Weather-Ometer in accordance with ASTM Method D750-68.

Carbon black pigmenting dispersions were mixed by preparation of equal parts by weight of fine thermal carbon black (P33) and trioctyl phosphate (TOF). Dispersion of the carbon black in the TOF was attained by use of a Waring blender.

RESULTS AND DISCUSSION

As previously described,[1] the liquid Adiprene L-315 and LD955 polymers appeared to be excellent materials for consideration in the fabrication of butt stocks, butt pads, and artillery handwheels. For these polymers to be useful in the foregoing component applications, more detailed information is required than was available at the time of the previous report.

Various liquid polyether urethane systems were compounded and evaluated for physical properties, mechanical properties, and environmental stability Results are summarized in Table I.

Almost all liquid urethane materials in the 65 to 85 Shore D hardness range have a pot life of less than five minutes. On a production basis with a casting machine, a pot life as short as this might often be desirable However, on a laboratory scale for which mechanized casting equipment is unavailable and on a production basis on which large parts or parts having complicated detail or geometry are involved, a longer pot life is desirable or necessary

Although pot life is not listed in Table I, increasing the pot life of the 65 to 85 Shore D liquid polyether urethanes was an objective Glycol curatives were not investigated, even though pot life can be extended by their use, because these curatives, when used with liquid polyether urethanes often produce vulcanizates with reduced physical properties, especially tensile strength Curene L is an amine curative known to provide increased pot life.

The Adiprene LD955 provides excellent properties with either MOCA or Curene L as the curative (Table I) Greatly improved pot life also resulted when Adiprene LD955 was cured with Curene L Vibrathane B604 is a material similar to the Adiprenes and also benefits greatly in pot life when cured with Curene L.

Compound U80-69 listed in Table I is based on a two-component system, both components are liquids at room temperature. Because both components are liquid and are normally mixed at room temperature, processing variables and complexities associated with the more common solid amine curatives are eliminated or greatly reduced.

All compounds listed in Table I exhibited high original tensile strength, a characteristic of the amine-cured polyether urethanes. Elongation also was fairly high, with the exception of the 10 per cent value measured on Compound U80-69. This low elongation could be a deterrent to the use of this material in butt stocks, butt pads, and handwheels in which a greater degree of flexibility is desirable to prevent breakage during periods of impact, twisting, bending or torque.

Since these materials, if used in butt stocks or handwheels, are likely to be exposed to a variety of outdoor environmental conditions, many compounds in Table I were evaluated for resistance to environmental deterioration. Results after 500 hours exposure in a Weather-Ometer show that carbon black offers a fair degree of protection to ultraviolet (UV) deterioration when used at 0.5 pphr. The UV protection of these carbon black pigmented compounds is increased by the addition of 0.75 pphr of Wing Stay T. Wing Stay T used at this level, however, lowers the original stress-strain properties. Evaluation at lower levels of Wing Stay T was not performed, but this would seem desirable to determine whether suitable UV protection can be obtained without the drop in original properties. Compound U80-69 offered excellent resistance to Weather-Ometer aging as received without further compounding for such protection.

Shear strength values (Table I) were used in establishing the engineering design for artillery handwheels. Details covering handwheel fabrication and testing are contained in a separate report entitled "Development of Polyurethane Handwheels for Artillery."

All compounds listed in Table I were evaluated for resistance to various servicing and nonservicing fluids, and semifluids with which these compounds are likely to come in contact if used in a butt stock or artillery handwheel application. Change in volume and hardness after exposure to the various fluids was used as measures for resistance; these results are summarized in Table II. All compounds show good resistance to the test fluids, with the exception of gasoline and insect repellent. However, total immersion for seven days is considered severe.

TABLE II

FLUID RESISTANCE OF LIQUID POLYETHER URETHANE VULCANIZATES

(See Table I for Formulations)

	U80-46	U80-58	U80-49	U80-57	U80-62	U80-71	U80-63	U80-69	U80-72
Original Shore D Hardness	70	67	77	75	72	70	73	78	77
Water Immersion, 70 hrs/212°F									
Volume Increase, %	1.8	1.1	2.3	2.0	1.8	2.1	2.1	4.3	2.7
Shore D Hardness	55	54	56	56	53	61	55	62	57
Volume Increase, 7 days/75°F, %									
Water	1.7	1.0	3.2	2.8	4.2	3.7	4.3	4.7	1.4
Gasoline	11.3	11.1	19.6	12.5	16.7	15.2	15.7	2.3	5.3
Kerosene	2.5	2.6	1.5	3.1	4.8	5.7	2.2	2.8	0.5
Dry-Cleaning Fluid	3.0	3.6	2.7	2.7	4.4	2.0	1.3	1.6	0.3
Diesel Fuel	3.0	1.7	2.7	1.7	4.0	3.0	2.8	0.8	0.3
MIL-L-14107 Lubricating Oil	0.2	0.0	0.0	1.5	1.8	0.0	4.4	0.6	2 4
VV-L-800 Lubricating Oil	0.0	0.2	0.9	0.7	2.0	1.6	3.3	0.2	1.7
MIL-L-46000 Lubricating Oil	0.7	0.6	0.4	0.3	0.5	0.2	2.4	1.0	2.2
Insect Repellent	11.8	20.5	17.0	17.2	13.8	12.9	20.7	3.7	58.0
Rifle Bore Cleaner	2.5		5.1	3.5	5.6	5.0	4.5	1.6	3.2
Shore D Hardness after 7 days/75°F, %									
Water	65	63	70	70	66	64	67	74	71
Gasoline	66	65	69	69	65	63	67	79	73
Kerosene	70	71	76	76	71	68	75	79	76
Dry-Cleaning Fluid	69	70	75	76	71	69	76	80	76
Diesel Fuel	71	71	76	76	70	69	76	78	77
MIL-L-14107 Lubricating Oil	72	71	76	76	72	71	77	80	77
VV-L-800 Lubricating Oil	72	71	76	76	71	71	76	80	77
MIL-L-46000 Lubricating Oil	70	71	75	76	71	70	77	79	78
Insect Repellent	65	59	66	67	63	64	66	79	55
Rifle Bore Cleaner	67		69	72	53	63	71	79	74

Even if a weapon is subjected to such exposure of gasoline and insect repellent, the belief is that the weapon would remain serviceable until a suitable replacement part could be obtained. However, efforts to improve the resistance of these materials to gasoline and insect repellent should be included in any future work.

For further evaluation of liquid urethane materials, M16A1 butt stocks were fabricated and tested with the use of current M16A1 glass-filled phenolic stock as a control for comparison purposes Since a one-piece butt stock - butt pad combination is more desirable than the current separate butt stock - butt pad combination, an RTV silicone mold was fabricated for the purpose of integral molding. This basically three-piece mold and the inserts necessary for the molding of undercuts to mount and latch the trap door is shown in Figure 1. With this mold, butt stocks were fabricated from Compound U80-63, listed in Table I. Test results obtained on these urethane butt stocks and the current production glass-filled phenolic are summarized in Table III. The results described in Table III are illustrated in Figures 2 through 6.

These data and figures show that the urethane butt stocks are superior to the current urethane foam-filled glass-phenolic commercial butt stock The only test that was destructive to the urethane butt stocks was that of impacting at -67 F (Figure 3) Only foam-filled glass phenolic commercial butt stocks are shown in Figures 5 and 6 since no damage was incurred by the urethane butt stocks during these tests

A comparison of some of the other important characteristics of commercial phenolic and experimental urethane butt stock is summarized in Table IV Comments listed in this table are self-explanatory

The opinion of an established manufacturer of castable urethane products was obtained as to the feasibility of molding the M16A1 butt stock - butt pad on a production scale at a cost competitive with the present production version Mass production is possible at a cost of approximately five dollars per butt stock The molding of the butt stock and the butt pad as an integral piece, however, would be prohibitively expensive due to the cost of molding undercuts into the butt pad portion to mount the trap door

TABLE III

PHYSICAL TESTING OF URETHANE AND GLASS-FILLED PHENOLIC BUTT STOCKS

PROPERTY TESTED*	POLYETHER URETHANE COMPOUND U80-63 Table I	HIGH-IMPACT GLASS-FILLED PHENOLIC (GPI-100)
Impact Strength at +75°F	Slight crease or indentation after 210 ft/lb blow. Illustrated in upper half of Figure 2.	Phenolic outer shell cracked and shattered after 40 ft/lb blow. Also chipping and shattering of foamed inner core. Illustrated in lower half of Figure 2.
Impact Strength at -67°F	Repeated 50 ft/lb blow caused no damage. At 60 ft/lbs breakage and shattering occurred. The upper half of Figure 3 illustrates the results after 60 ft/lbs of impact.	Repeated 15 ft/lb blows caused no damage. At 20 ft/lbs breakage and shattering of both the phenolic outer shell and foam core occurred. The lower half of Figure 3 illustrates the results after 20 ft/lbs of impact.
Compressive Strength at +75°F	Bending and deflection occurred at a load of 3000 lbs. Some recovery after loading was released. The upper half of Figure 4 illustrates the results.	The phenolic outer shell cracked and failed at 3770 lbs. The lower half of Figure 4 illustrates the results.
Bending Strength at +75°F	No damage occurred after applying 80 lbs of force and deflecting 25°. Complete recovery after loading force was released.	Broke at 210 lbs of loading. No deflection occurred. The upper half of Figure 5 illustrates the results.
Torsional Strength at +75°F	No damage occurred after applying 105 lbs of force and deflecting 22°. Complete recovery after loading force was released.	Broke at 158 lbs of loading and 7° deflection. The lower half of Figure 5 illustrates the results.
On Rifle Drop Test from 5 Feet at +75°F	No damage occurred after repeated dropping at various angles.	Cracked when dropped on toe and heel at a 45° angle. Figure 6 illustrates the results.

*All tests except the rifle drop-test were run on butt stocks detached from the rifle and without a buffer tube installed.

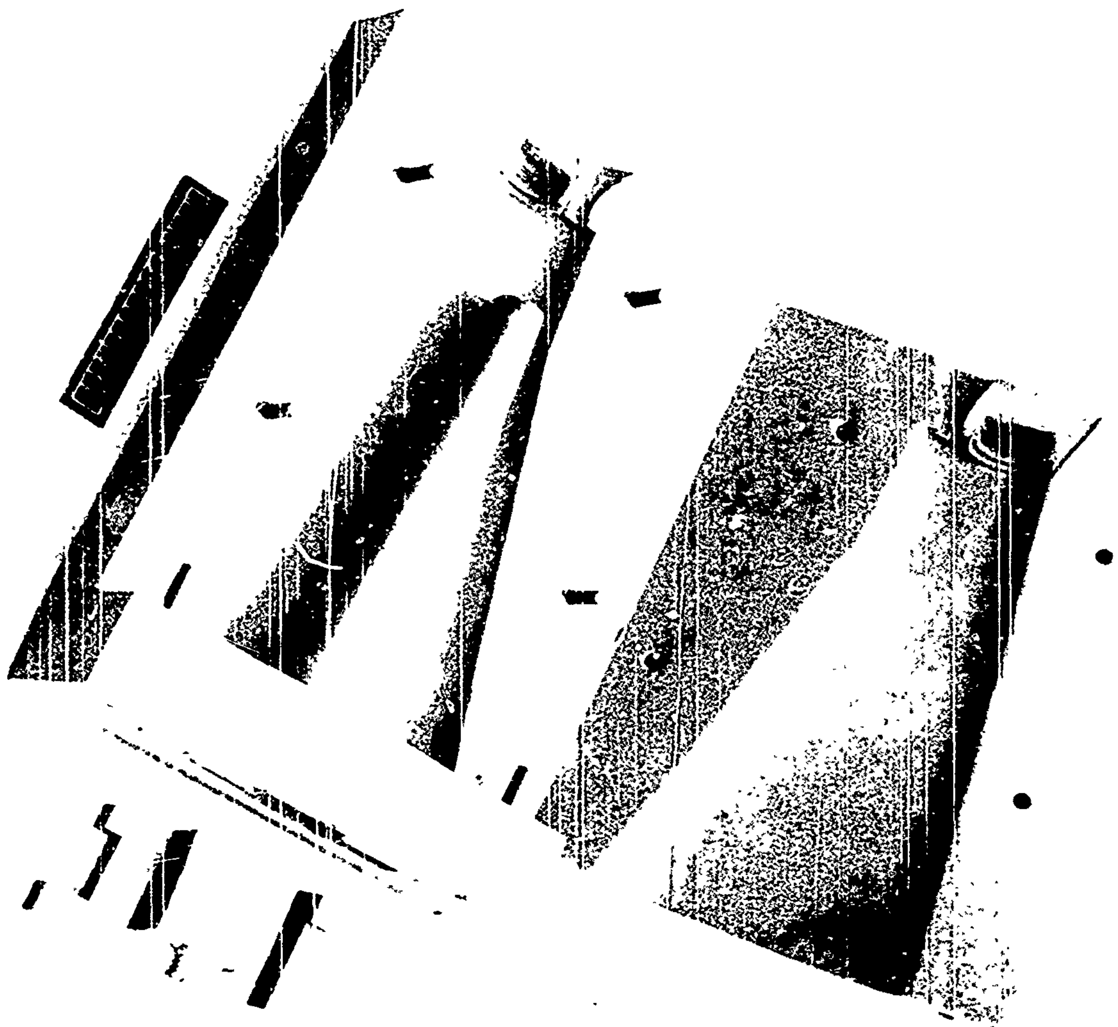

FIGURE 1 M16A1 butt stock mold with inserts required for molding undercuts

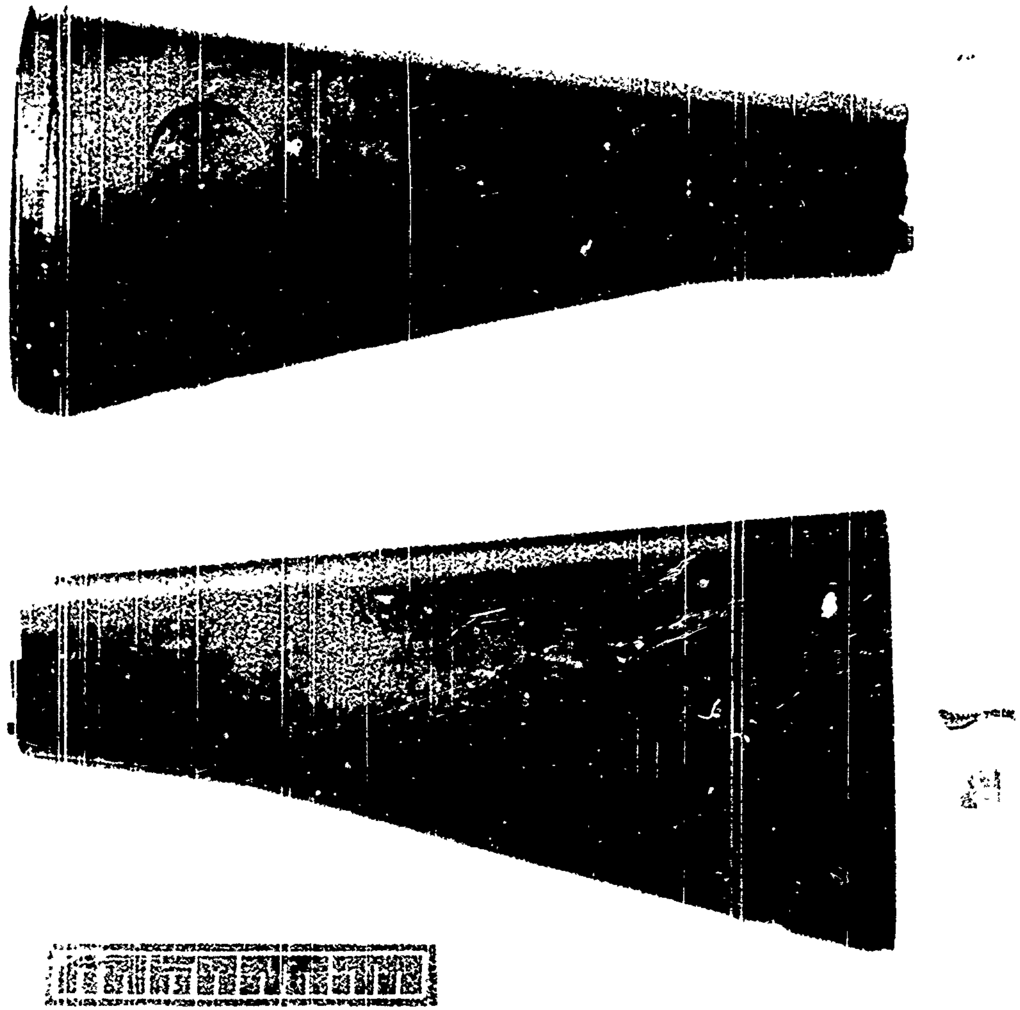

FIGURE 2 Top view, M16A1 urethane butt stock after 210 ft/lb impacting blow at +75°F.
Bottom view, M16A1 glass-filled phenolic butt stock after 40 ft/lb impacting blow at +75°F.

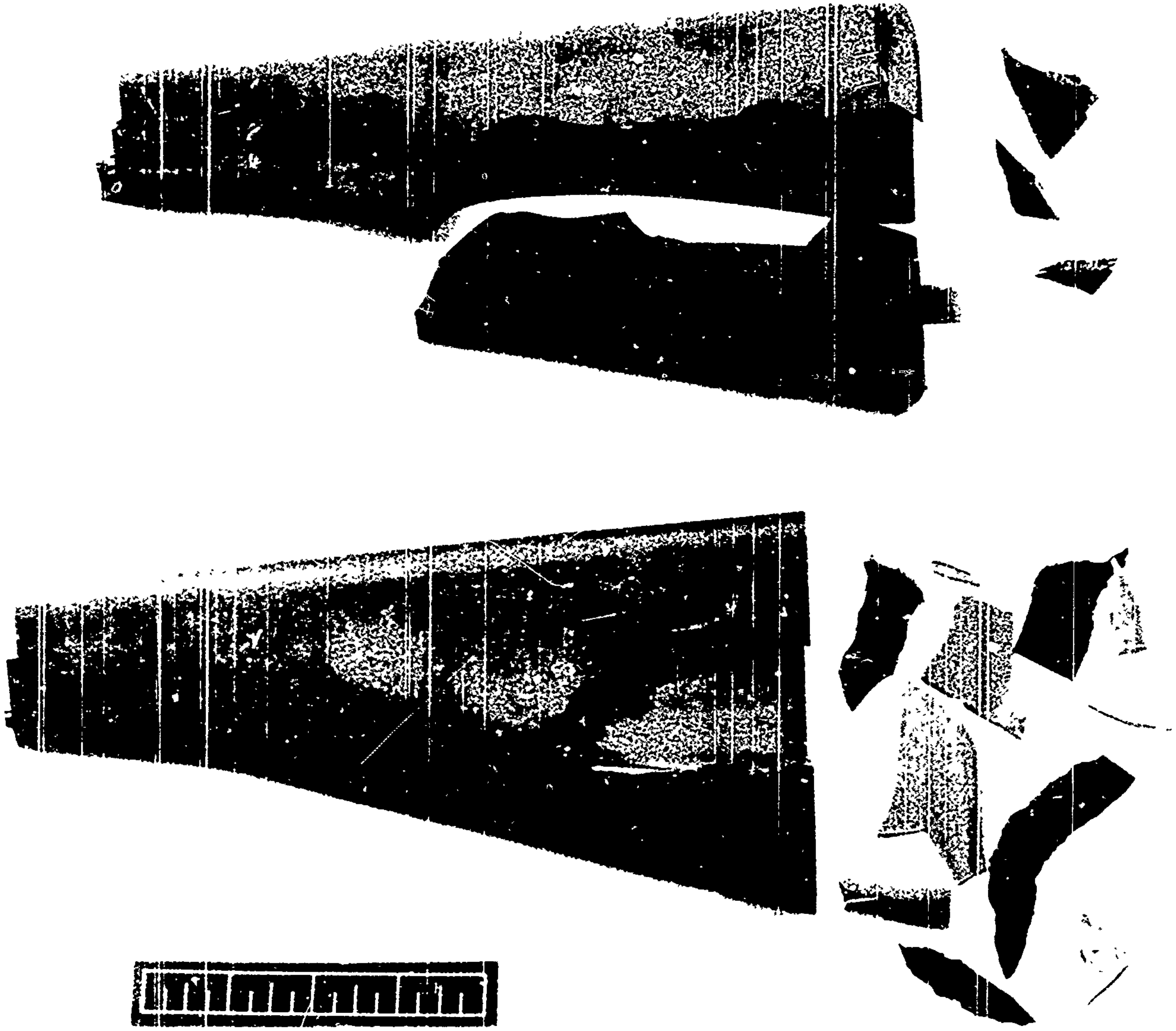

FIGURE 3 Top view, M16A1 urethane butt stock after 60 ft/lb impacting blow at -67°F.
Bottom view, M16A1 glass-filled phenolic butt stock after 20 ft/lb impacting blow at -67°F.

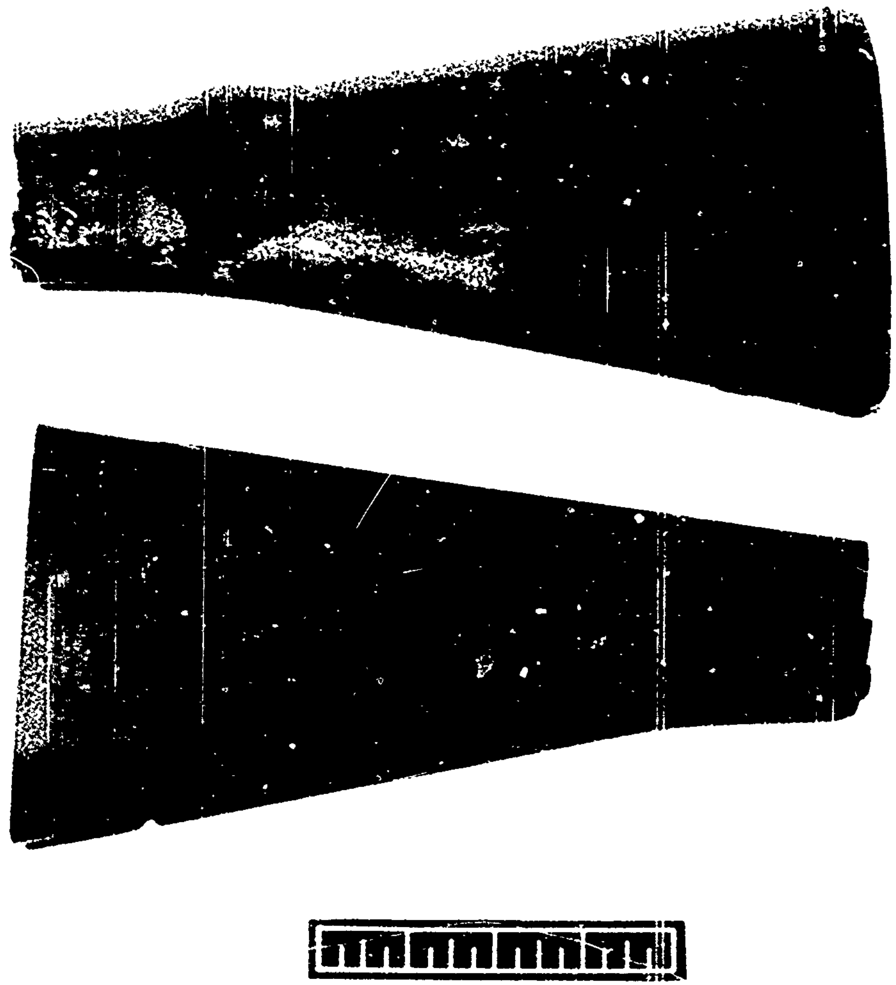

FIGURE 4 Top view, M16A1 urethane butt stock after 4440 lb of compression loading.
Bottom view, M16A1 glass-filled phenolic butt stock after 3770 lb of compressive loading.

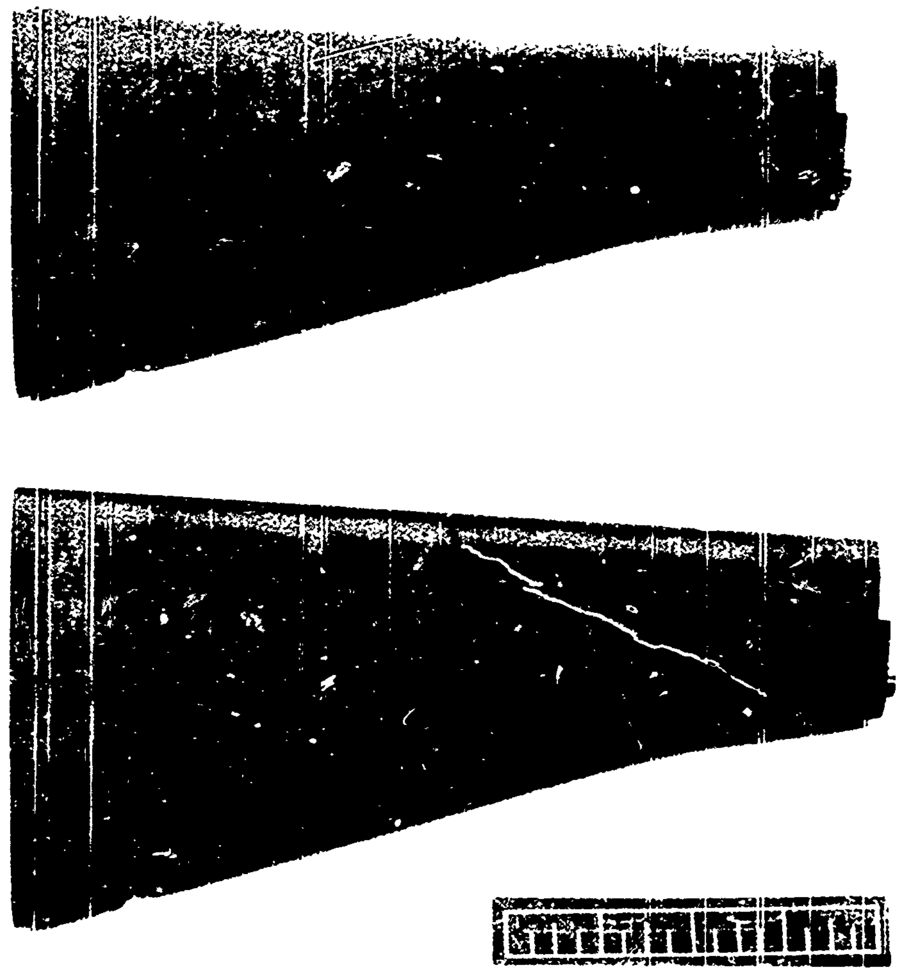

FIGURE 5 Top view, M16A1 glass-filled phenolic butt stock after 210 lb of bending force.
Bottom view, M16A1 glass-filled phenolic butt stock after 158 lb of torsional loading.

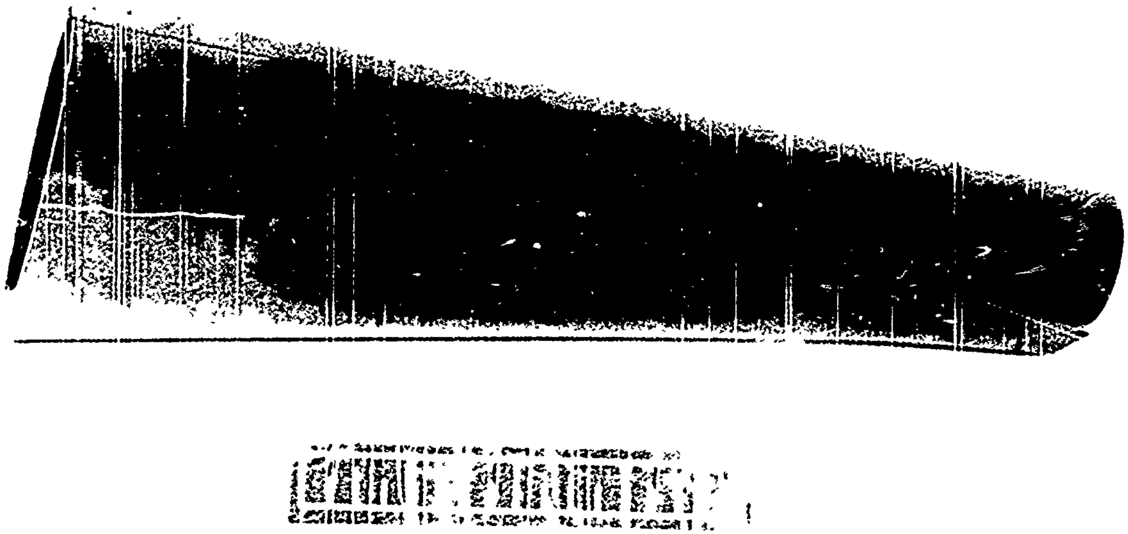

FIGURE 6 M16A1 glass-filled phenolic butt stock after on rifle drop-test from 5 ft at +75°F

TABLE IV

MISCELLANEOUS DATA COMPARISON OF PHENOLIC PRODUCTION VS EXPERIMENTAL URETHANE BUTT STOCKS

CHARACTERISTIC	EXPERIMENTAL URETHANE	PHENOLIC PRODUCTION
Weight, grams	355	350
Visual impreceptibility to the enemy	Excellent. Resists scratching and marring well. If scratched or marred, exposed surface is nonreflective and presents no camouflage problem.	Poor. When scratched or marred light reflecting glass fibers are exposed, thus a camouflage problem occurs.
Acoustical impreceptibility to the enemy	Excellent. Generates little noise if brushed, bumped or impacted.	Poor. Generates loud, hollow, ringing noise if brushed, bumped or impacted.
Environmental durability	Excellent.	Fair to poor. In areas of high humidity, the low-density foamed-core has a tendency to deteriorate and to mechanically separate from the glass-filled phenolic outer shell.